# Chapter 3. ENVIRONMENTAL SETTING

## 3.1 General

Pacific herring, *Clupea pallasi*, are found throughout the coastal zone from northern Baja California on the North American coast, around the rim of the North Pacific Basin and Korea on the Asian coast (Outram and Humphreys 1974, Hart 1973). In California, herring are found offshore during the spring and summer months foraging in the open ocean. Beginning as early as October and continuing as late as April, schools of adult herring migrate inshore to bays and estuaries to spawn. Schools first appear in the deep water channels of bays to ripen (gonadal maturation) for up to two weeks, then gradually move into shallow areas to spawn. The largest spawning aggregations in California occur in San Francisco and Tomales bays. San Francisco Bay is also near the southern end of the range for Pacific herring (Miller and Schmidtke 1956).

Spawning occurs in the intertidal and shallow subtidal zones. Males release milt into the water column while females extrude adhesive eggs on a variety of surfaces including vegetation, rocks, and man-made structures such as pier pilings, boat bottoms, rock rip-rap, and breakwater structures. Embryos (fertilized eggs) typically hatch in about ten days, determined mainly by water temperature. Larval herring metamorphose into juvenile herring in about ten to twelve weeks. In San Francisco Bay, juvenile herring typically stay in the Bay through summer, and then migrate out to sea. Where juvenile herring migrate to once they leave the bays and estuaries is not known or understood.

Most of the herring fisheries occur during the spawning season. The roe herring gill net fisheries catch herring as they move into the shallows to spawn when the eggs are ripest. The product, *kazunoko*, from this fishery is the sac roe (eggs) in the females which are processed and exported for sale to Japan. California's roe herring fisheries occur in the Crescent City Harbor area, Humboldt Bay, Tomales Bay, and San Francisco Bay.

The San Francisco Bay herring eggs-on-kelp fishery suspends Giant kelp, *Macrocystis pyrifera*, from rafts for herring to spawn on in shallow water areas.

The kelp is harvested near the Channel Islands and/or in Monterey Bay and then transported to San Francisco Bay. The product of this fishery is the egg-coated kelp blades that are processed and exported to Japan. This product, *komochi* or *kazunoko kombu*, is served as an appetizer typically during New Year's celebrations

The only existing ocean fishery for herring in California occurs during the non-spawning season in Monterey Bay. Landings from this fishery enter the aquarium food and bait markets. Small fisheries for fresh fish are also permitted during the non-spawning season in Tomales Bay and San Francisco Bay.

Herring are a food source for many species of birds, fish, invertebrates, and mammals. Predation is particularly high during spawning when adult fish and eggs are concentrated and available in shallow areas. Predation by birds and fish during the egg stage, when eggs are deposited in the intertidal and shallow subtidal zones, is a significant cause of natural mortality for herring.

The roe herring fishery in California has been intensively regulated since its inception in 1973, at first by the California State Legislature, then by the Fish and Game Commission (Commission). Department of Fish and Game (Department) estimates of the spawning population biomass have provided a critical source of information used for establishing fishery quotas to control the harvest of herring and provide for the long-term health of the herring resource. A thorough description of the environmental setting is provided in Chapter 3 of the 1998 Final Environmental Document (FED), which includes Pacific herring life history, ecology, status of stocks and fisheries at that time, and biological and environmental descriptions of herring fishery locations (Crescent City area, Humboldt Bay, Tomales Bay, San Francisco Bay, and Monterey Bay).

### 3.2 Spawning Population Estimation Methods

Annual estimates of spawning biomass are made by the Department in Tomales and Humboldt bays using spawn deposition surveys (refer to section 3.2.1). For San Francisco Bay, the Department estimated spawning biomass using the spawn deposition surveys from 1973-1974 through 1988-89 seasons.

From the 1990-91 through 2001-02 seasons, the Department estimated spawning biomass from a combination of spawn deposition and hydroacoustic surveys (refer to section 3.2.2) for San Francisco Bay. Beginning with the 2003-04 season, the Department reverted to using the spawn deposition surveys alone for biomass estimation (refer to section 3.2.3). In addition to the estimates of spawning biomass, the Department collects fishery independent age composition data from the population, as well as fishery dependent age composition from the commercial catch. All of the information collected by the Department, including ocean conditions, is used in annual population assessments.

### 3.2.1 Spawn Deposition Surveys

Pacific herring enter Crescent City Harbor, Humboldt, Tomales, and San Francisco Bays in schools (or waves) to spawn in the intertidal and shallow subtidal portions of the Bay from November through March each year. Females extrude adhesive eggs on a variety of ‘clean’ substrates (i.e., free from silt) including vegetation, rocks, shell fragments, pier pilings, boat bottoms, concrete riprap and seawalls. Embryos take about ten days to develop and hatch.

The spawn survey consists of: 1) a systematic search for herring spawning activity throughout the spawning season; 2) surveying spawns to estimate the biomass of adult spawners; and 3) adding landings to adult spawner biomass to estimate total biomass of each school. The basic methodology (Spratt, 1981) of the survey has remained the same since 1973, with some modifications over the years to increase the survey’s accuracy. Watters et al. (2004) describes in more detail the field and laboratory methods used to conduct the survey.

The spawn survey was designed to estimate the total number of eggs spawned and to convert that estimate to the total tons of spawning adults, using a conversion factor based on fecundity (the number of eggs per unit body weight of females) and the ratio of males and females in the school. The area of the spawn is measured and samples are collected from which the density (number of eggs/$m^2$) of eggs is calculated. This is expanded to the total area of the spawn to estimate the total number of eggs spawned. The total eggs spawned are then converted to tons of spawning adults. The sac roe fishery typically catches Pacific herring just prior to spawning, while the herring eggs-on-kelp fishermen harvest product post-spawning. Landings data are collected and tallied on a daily basis. The tons of sac roe herring landed are then added to the estimated tons of spawners. Herring eggs-on-kelp landings are also added after conversion to tons of whole fish to estimate the total size of a school (or wave) of herring.

### 3.2.2 San Francisco Bay Hydroacoustic Surveys

Hydroacoustic surveys determine the size and density of herring schools entering the Bay by transmitting sound waves through the water column using an echo sounder and quantifying the returning echoes or “marks”. Hydroacoustic surveys were composed of quantitative and qualitative components. Qualitative surveys were conducted primarily with a video echo sounder to verify the location and distribution of herring schools. Sampling gear, primarily midwater trawl, was used to identify or differentiate the “marks” as herring from other schooling species commonly found in the Bay such as Northern anchovy (*Engraulis mordax*) and white croaker (*Genyonemus lineatus*). Qualitative surveys were carried out prior to quantitative surveys.

The Department used two quantitative survey methods to estimate biomass, “visual” integration and echo integration. The visual integration method was developed for herring biomass estimation in 1982 and continued to the present (Reilly and Moore 1983). Echo integration was used from 1986 through 1990 before being discontinued due to logistical issues (FED 1998). This method is fully described in Reilly and Moore 1987.

Quantitative surveys were conducted for each detected school that entered the Bay after it was determined by sampling and qualitative surveys that the school ripened, the school coalesced, and spawning, based on observed behavior, was imminent. Once school location and school boundaries were determined by qualitative surveys (“metering”) using an echo sounder, the quantitative survey was initiated at the west end, or “upstream” end, of the school.

Visual integration surveys employed a paper recording echo sounder and a GPS (global positioning system) device. An echogram, a paper recording produced by the echo sounder, provided a visual recording of the school density and area information. This was obtained by taking systematic diagonal “zig zag” transects from one end of the herring school to the other. Each transect was terminated when either the herring “marks” disappeared or when the course taken by the skipper conflicts with land or other obstacles (i.e., vessels and buoys). A turn by the vessel was made to initiate a new transect. Turn location data from positioning location equipment were recorded on the echogram. In the laboratory, transects were plotted on charts from the location information recorded on the echogram.

Densities of herring represented in each transect were determined based on comparisons to calibration standards (i.e., visual integration). Marks that were determined by sampling or appeared to be non-herring were deducted or omitted from analysis. The densities were averaged for each transect and multiplied by the school surface area to determine the number of tons contained within the area surveyed (Oda 1994).

### 3.2.3 Stock Assessment and Review of Survey Methods for San Francisco Bay

Following the 2002-03 herring season, Department biologists conducted a comprehensive review of the status of the San Francisco Bay herring population. The review included an analysis of several long-term data sets, some of which date back to the beginning of the roe fishery in 1973, including spawning biomass estimates, age composition of the population, age composition of the catch, length and weight at age, and environmental data. In addition, the Coleraine Model, a stock assessment model, was utilized to assess the status of the population. The Department’s use of the Coleraine Model and its results were subjected to an independent peer review, administered through California

Sea Grant (Appendix B: Peer Review).

The Department also conducted an analysis of the two survey methods used to estimate biomass in San Francisco Bay: the spawn deposition survey and the hydroacoustic survey (Sections 3.2.1 and 3.2.2). The two surveys were used in combination on a school-by-school basis to derive a biomass estimate from the 1989-90 through 2001-02 seasons. The two surveys were usually combined by choosing the higher of the two estimates. Sometimes this resulted in a total biomass estimate for the season that exceeded the total for either survey. Beginning with the 1993-94 season, the total biomass estimated by each survey began to diverge, with the hydroacoustic survey estimates consistently larger than spawn survey estimates. In addition, in later years the trends depicted by the two survey estimates began to differ, with the hydroacoustic survey estimates fluctuating up and down from year to year, and the spawn survey estimates remaining low.

Because the biomass estimate from one season is used to set the quota for the following season, a basic assumption in using a survey is that its biomass estimate from one year will be a reasonable estimator of biomass in the following year. The analysis found that the hydroacoustic survey was less consistent and a poor predictor of itself in the following year, while the spawn survey followed more consistent trends, predicting itself in the following year reasonably well. In addition, when compared with the modeled biomass estimates from the Coleraine model, hydroacoustic survey biomass estimates did not correlate, while the spawn survey biomass showed a high correlation with modeled biomass.

This analysis was also reviewed by the peer review panel. In reviewing the biomass estimates from the two survey methodologies, the peer review panel found that the spawn deposition survey on average tends to underestimate biomass by about 10 percent and the hydroacoustic survey tends to overestimate biomass by about 20 percent on average. The panel found that the Department's method of combining the two surveys, which often involved using the higher of the two estimates on a school by school basis, has contributed to excessive quotas by overestimating biomass.

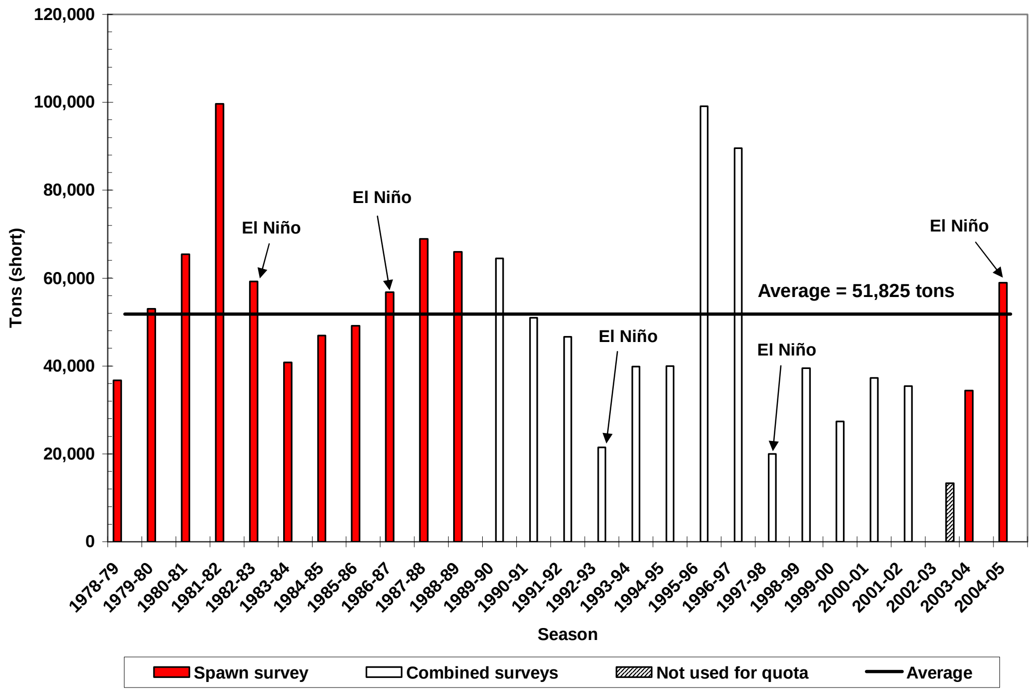
The panel recommended that the spawn survey be used as the primary index of abundance and as the biomass estimate for setting the fishery quota until an integrated catch-age model can be developed and verified for San Francisco Bay. They also recommended that hydroacoustic surveys be continued to support the location and timing of the spawn deposition survey in conjunction with sampling herring schools that are critical for collecting population age structure information.

Following the Department's own analysis of the two survey's biomass estimates and the peer review panel's analysis, in 2003-04 the Department reverted to using the spawn survey biomass estimate to base quota recommendations on for San Francisco Bay. This change was implemented to improve the consistency and accuracy of biomass estimation. Controversy surrounding that decision is discussed further in Section 3.6 of this DSED.

### 3.3 Status of the San Francisco Bay Spawning Population

The 2004-05 spawning biomass estimate is 58,934 tons (including catch), a 71 percent increase over last season's estimate of 34,400 tons (Figure 2.2). It is the first spawning biomass estimate to exceed the long-term average, 51,825 tons, used to set fishery quotas since the 1996-97 season, following seven consecutive seasons of below-average spawning biomass.

**Figure 2.2. San Francisco Bay Pacific herring spawning biomass estimates 1978-79 to 2004-2005**



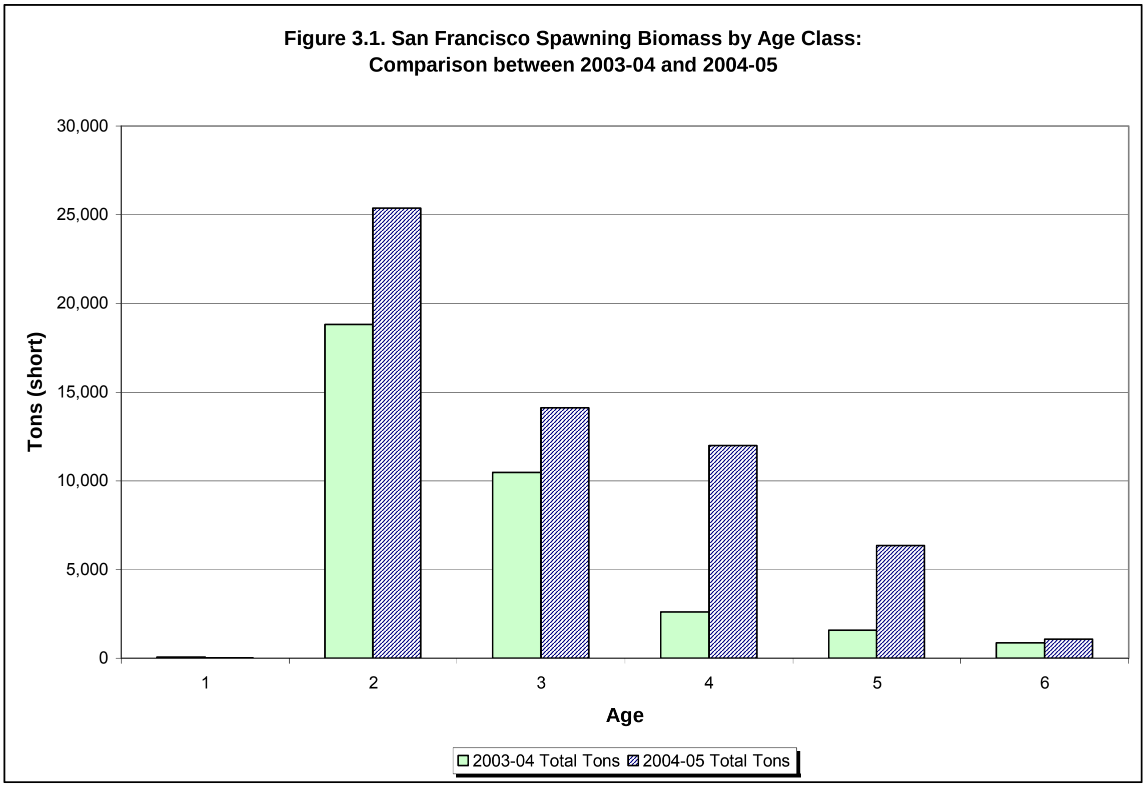

Length at age information from the 2003-04 season was applied to this season's length data to develop a preliminary population age structure. The more accurate method of reading otoliths, hard ear-bone structures, for obtaining age composition for the current season will be conducted this summer. The updated ages will then be incorporated into the FSED for 2005.

The preliminary age composition indicates strong recruitment of two-year-old herring, approximately 128 percent by number above the long-term mean and 33 percent higher than the 2003-04 season (Table 2.5). There were significant increases in the numbers of 3-, 4-, 5-, and 6-year-old sized herring (35, 358, 302, and 23 percent by number respectively from the 2003-04 season); however, the estimated numbers of 3-, 4-, and 5-year-olds were average and 6-year-olds were below the long-term averages. The greatest increase in spawning biomass by age group appears to be the four-year-old cohort (Figure 3.1).

Table 2.5. Estimated Numbers (x 1,000) of Herring-at-Age in the San Francisco Bay Spawning Population, 1982-83 to present

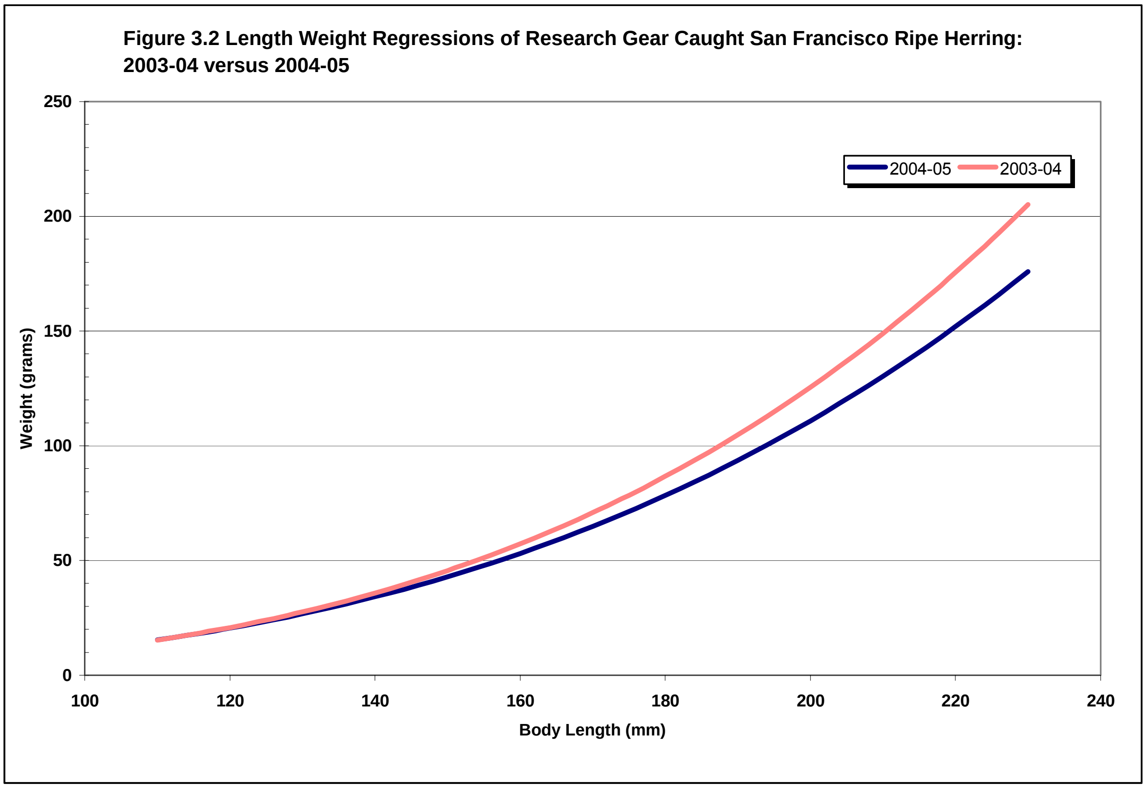
| | Age and Percent Composition | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Season | 1 | % | 2 | % | 3 | % | 4 | % | 5 | % | 6 | % | 7 | % | 8 | % | 9 | % | Total |
| 82-83 | [a] | N/A | 87,908 | 14.8 | 149,971 | 0.3 | 182,936 | 30.7 | 118,040 | 19.8 | 30,478 | 5.1 | 17,177 | 2.9 | 8,121 | 1.4 | 797 | 0.1 | 595,428 |
| 83-84 | [a] | N/A | 332,699 | 56.6 | 69,654 | 0.1 | 92,565 | 15.8 | 73,840 | 12.6 | 17,306 | 2.9 | 1,168 | 0.2 | 117 | 0 | 0 | 0.0 | 587,349 |
| 84-85 | [a] | N/A | 184,695 | 38.7 | 190,998 | 40.0 | 46,613 | 9.8 | 22,153 | 4.6 | 25,914 | 5.4 | 6,652 | 1.4 | 688 | 0.1 | 0 | 0.0 | 383,033 |
| 85-86 | [a] | N/A | 162,422 | 32.4 | 160,613 | 32.1 | 126,535 | 25.3 | 26,790 | 5.3 | 16,038 | 3.2 | 7,752 | 1.5 | 717 | 0.1 | 182 | 0.0 | 501,049 |
| 86-87 | [a] | N/A | 168,962 | 29.2 | 194,365 | 33.6 | 134,528 | 23.2 | 64,598 | 11.2 | 9,182 | 1.6 | 6,175 | 1.1 | 1,065 | 0.2 | 246 | 0.0 | 579,121 |
| 87-88 | [a] | N/A | 233,193 | 30.6 | 292,508 | 38.3 | 136,604 | 17.9 | 66,494 | 8.7 | 25,337 | 3.3 | 5,027 | 0.7 | 3,939 | 0.5 | 0 | 0.0 | 763,102 |
| 88-89 | [a] | N/A | 146,525 | 25.8 | 222,058 | 39.0 | 139,906 | 24.6 | 44,435 | 7.8 | 12,310 | 2.2 | 3,030 | 0.5 | 534 | 0.1 | 0 | 0.0 | 568,798 |
| 89-90 | [a] | N/A | 294,631 | 37.6 | 237,377 | 30.3 | 136,248 | 17.4 | 84,361 | 10.8 | 23,970 | 3.1 | 6,572 | 0.8 | 0 | 0 | 0 | 0.0 | 783,159 |
| 91-92 | 1,356 | 0.3 | 13,666 | 3.0 | 126,016 | 28.0 | 206,930 | 45.2 | 82,870 | 18.1 | 23,764 | 5.2 | 3,490 | 0.8 | 0 | 0 | 0 | 0.0 | 458,092 |
| 92-93 | 0 | 0 | 48,925 | 20.5 | 50,398 | 21.1 | 79,045 | 33.1 | 51,713 | 21.7 | 8,642 | 3.6 | 0 | 0 | 0 | 0 | 0 | 0.0 | 238,723 |
| 93-94 | 11,485 | 2.6 | 22,403 | 5.1 | 134,870 | 31.0 | 160,335 | 36.9 | 63,331 | 14.6 | 25,926 | 6.0 | 4,808 | 1.1 | 355 | 0.1 | 0 | 0.0 | 423,513 |
| 94-95 | 2,276 | 0.5 | 39,363 | 9.0 | 236,783 | 54.1 | 94,833 | 21.7 | 42,850 | 9.8 | 18,223 | 4.2 | 3,196 | 0.7 | 0 | 0 | 0 | 0.0 | 437,524 |
| 95-96 | 3,142 | 0.3 | 483,164 | 38.9 | 359,357 | 29.0 | 282,069 | 22.7 | 81,768 | 6.6 | 28,904 | 2.3 | 1,687 | 0.1 | 0 | 0 | 0 | 0.0 | 1,240,091 |
| 96-97 | 1,184 | 0.1 | 290,497 | 29.1 | 359,459 | 36.0 | 183,370 | 18.4 | 120,029 | 12.0 | 33,098 | 3.3 | 8,935 | 0.9 | 270 | 0 | 0 | 0.0 | 996,842 |
| 97-98 | 42 | 0 | 45,092 | 17.2 | 129,411 | 49.3 | 65,637 | 25.0 | 18,724 | 7.1 | 2,259 | 0.9 | 1,430 | 0.5 | 0 | 0 | 0 | 0.0 | 262,595 |
| 98-99 | 1,931 | 0.4 | 256,816 | 52.0 | 54,306 | 11.0 | 114,835 | 23.2 | 56,915 | 11.5 | 9,729 | 2.0 | 558 | 0.1 | 978 | 0.2 | [b] | 0.0 | 496,068 |
| 99-00 | 1,440 | 0.4 | 103,490 | 30.4 | 154,260 | 45.3 | 48,150 | 14.1 | 29,000 | 8.5 | 4,310 | 1.3 | 0 | 0 | 0 | 0 | [b] | 0.0 | 340,650 |
| 00-01 | 255,158 | 36.0 | 178,401 | 35.43 | 185,748 | 36.9 | 65,555 | 13.0 | 24,267 | 4.8 | 126 | 0.0 | 0 | 0 | 0 | 0 | 0 | 0.0 | 709,255 |
| 01-02 | 5,788 | 1.5 | 157,182 | 39.6 | 138,752 | 35.0 | 75,088 | 18.9 | 15,383 | 3.9 | 4,265 | 1.1 | 152 | 0 | 0 | 0 | 0 | 0.0 | 396,610 |
| 03-04[c] | 2,473 | 0.5 | 328,257 | 65.5 | 122,072 | 24.3 | 26,641 | 5.3 | 14,848 | 3.0 | 7,225 | 1.4 | 0 | 0 | 0 | 0 | 0 | 0.0 | 501,516 |
| 04-05[d] | 1,096 | 0.1 | 442,928 | 55.4 | 164,566 | 20.6 | 122,103 | 15.4 | 59,676 | 7.5 | 8,875 | 1.1 | 0 | 0 | 0 | 0 | 0 | 0.0 | 799,244 |
| Mean | 22,096 | 3.3 | 191,146 | 31.7 | 177,681 | 30.3 | 119,973 | 21.8 | 55,314 | 10.0 | 15,992 | 2.8 | 3,705 | 0.6 | 839 | 0.1 | 68 | 0.0 | 586,814 |

Note: 1990-91 season was not included due to incomplete data set for that season; 2002-03 season spawning biomass estimate unresolved.
[a] 1-year-olds were not estimated, [b] 9-year-olds were not estimated, [c] includes corrected estimated numbers of herring, [d] percentages are the average percentages for all years, not the percentage that the average number represents




Although the numbers of six-year-old herring increased from the 2003-04 estimate, it appears that the numbers of six-year-old herring remain below average while herring older than six years are nearly absent from the population.

Length weight regression analysis of data taken from ripe herring sampled this season with research gear (midwater trawl, gill net, and throw net) indicates that herring were lighter in weight for a given length than the 2003-04 season. Ripe herring, male and female samples combined, weighed as much as 12 percent lighter for a given length than herring sampled in the 2003-04 season (Figure 3.2).




Samples taken from the commercial gill net fishery indicate the same trend in weight loss. The mean length of commercial gill net samples for the 2003-04 season was 187 millimeters (mm) Body Length (BL) and weights averaged 101 grams (g). This season the average length of the commercial catch increased to 191 mm BL; however, average weights of sampled fish declined to 98 g.

Poor growth of herring in 2004 is attributed to the effects of the 2004-05 El Niño and is likely to be one the factors that led to record low landings by the gill net fishery this season. Although the annual estimated spawning biomass is 71 percent higher than the 2003-04 season, and 4-, 5-, and 6-year-old sized herring increased a total of 14,000 tons from the previous season (Figure 3.1), the fishery was dismal. Herring exhibiting reduced weight and girth due to effects of El Niño are more likely to pass through gill net webbing, whereas, well-conditioned herring with higher weight to length ratios are more likely to be caught (Winters and Wheeler 1990). Additionally, this season's spawning population was dominated by younger fish; approximately 75 percent by number of the spawning biomass was composed by 2- and 3-year-old sized herring.

The earliest spawn occurred near November 2, 2004, and the latest spawn occurred on March 25, 2005. Spawns were recorded from the Marin Rod and Gun Club at Pt. San Quentin in the north to Coyote Pt. in the south. This season's vegetation survey revealed a substantial increase over recent years in density and area of eelgrass (*Zostera marina)* and *Gracilaria spp.* in Richardson Bay and Belvedere Cove. At some sites within Richardson Bay the increase was three-fold or greater over last year's densities. A substantial amount of *Gracilaria spp*. was also discovered for the first time in the subtidal area south of Candlestick Point.

The spawning season started off very slowly with only trace amounts of spawn found in Richardson Bay in November and at Crown Beach in Alameda in early December. The first measurable spawn of the season (2,876 short tons) occurred about December 12, 2004, in the Candlestick Pt. area, in the subtidal on *Gracilaria spp.* between Hunter's Point and Candlestick Pt., the intertidal around Candlestick Pt., and the subtidal south of Candlestick Pt., again on *Gracilaria spp.* This was the first time <u>subtidal</u> spawning was documented in this area in the 32-year history of the spawn survey, and the Department documented spawning here three more times during the 2004-05 spawning season (Table 3.1).

An unusually high amount of spawning occurred in the South Bay region (Candlestick Pt. south, including Sierra Pt., Oyster Pt., and Coyote Pt.) during 2004-05, with the majority occurring in the subtidal area around Candlestick Pt. Twenty-six percent of the total spawn escapement (not including catch) biomass estimate occurred in this area. Historically, the South Bay region has comprised only about 1 percent on average of the total spawn escapement biomass for San Francisco Bay.

Continuing the trend of recent years, the majority of spawning occurred in the North-Central Bay (Pt. Bonita to Pt. San Quentin, Pt. San Pablo to the Bay Bridge). Seventy-one percent of the 2004-05 season's total spawn escapement biomass occurred in North-Central Bay, with 58 percent of the season's total

Table 3.1. 2004-05 Pacific Herring Spawning Biomass Estimates for San Francisco Bay
All weights in short tons.

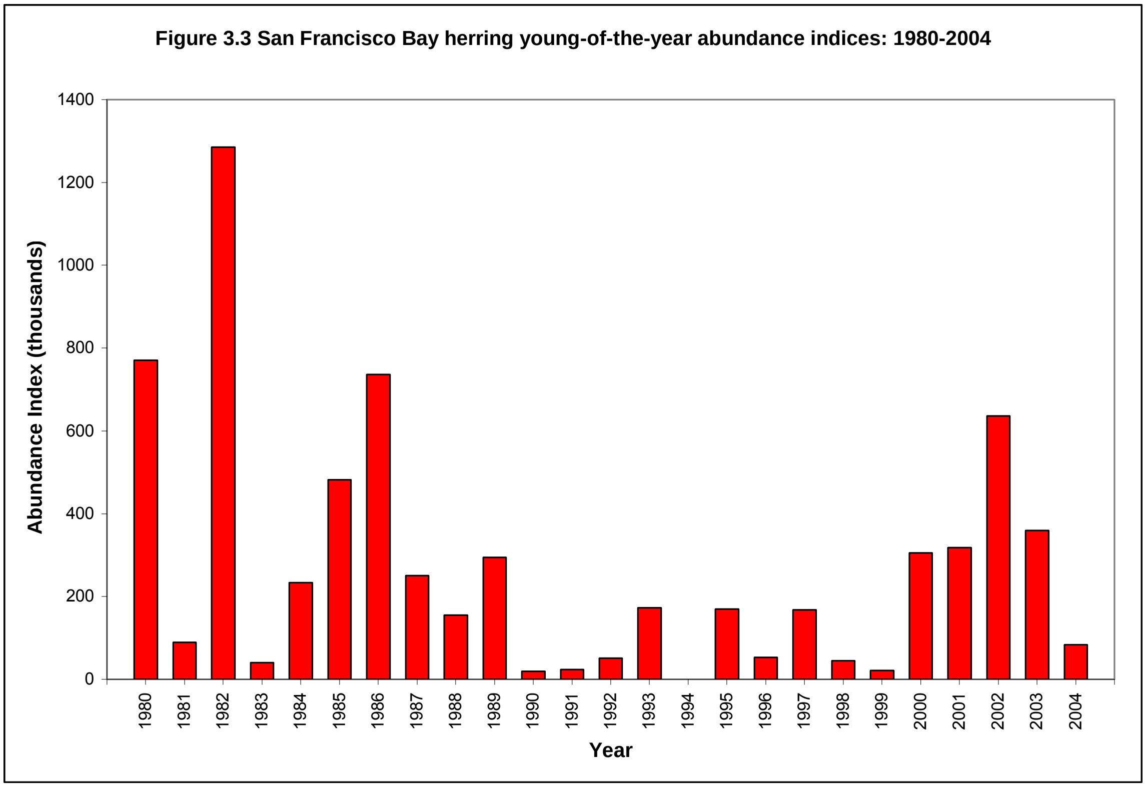
| Wave Number | Approx. Spawn Date(s) | Location(s) | Spawn Escapement Estimate | Catch | Spawning Biomass Estimate |
|---|---|---|---|---|---|
| 1 | 2-Nov-04 | Richardson Bay subtidal | Trace | NA | NA |
| 2 | 23-Nov-04 | Richardson Bay subtidal | Trace | NA | NA |
| 3 | 3-Dec-04 | Crown Beach Alameda | Trace | NA | NA |
| 4 | 12-Dec-04 | Cove between Candlestick Pt. and Hunter's Pt., subtidal south of Candlestick, intertidal Candlestick | 2,857 | NA | 2,857 |
| 4 | 15-Dec-04 | Oyster Pt. | 19 | NA | 19 |
| 5 | 16-Dec-04 | Richardson Bay subtidal | 1,630 | NA | 1,630 |
| 6 | 25 Dec 04 - 1 Jan 05 | Cove between Candlestick Pt. and Hunter's Pt., intertidal Candlestick Pt., subtidal south of Candlestick Pt. | 10,760 | NA | 10,760 |
| 6 | 30-Dec-05 | Cove between Candlestick Pt. & Hunter's Pt., intertidal Candlestick Pt., subtidal between Candlestick & Sierra Pt., Sierra Pt., Oyster Cove marina, Coyote Pt. | 3,587 | NA | 3,587 |
| 7 | 29-30 Dec 04 | Richardson Bay subtidal | 3,069 | NA | 3,069 |
| 8 | 4-10 Jan 05 | Richardson Bay subtidal | 3,029 | NA | 3,029 |
| 9 | 16-21 Jan 05 | Fort Baker to Sausalito intertidal, most marinas in Sausalito, Richardson Bay subtidal | 15,774 | 68 | 15,842 |
| 10 | 27-28 Jan 05 | Peninsula Pt., Belvedere subtidal | 164 | NA | 164 |
| 10 | 29 Jan-2 Feb 05 | Richardson Bay subtidal, Belvedere Cove intertidal and seawall | 7,255 | NA | 7,255 |
| 10 | 2-5 Feb 05 | (continuation of above spawn) Sausalito marinas, intertidal Sausalito to past sewage treatment plant | 709 | NA | 709 |
| 11 | 29-31 Jan 05 | South of Candlestick Point, trace in Hunter's Pt. Cove | 112 | NA | 112 |
| 11 | 4-Feb-05 | Oyster Pt. | 36 | NA | 36 |
| 12 | 5-8 Feb 05 | Pt. San Quentin to Elephant Rock | 3,392 | 77 | 3,469 |
| 13 | 20-Feb-05 | Belvedere Cove | 3 | NA | 3 |
| 13 | 22-25 Feb 05 | Richardson Bay | 3,761 | NA | 3,761 |
| 13 | 27-28 Feb 05 | Sausalito Marina | 226 | NA | 226 |
| 14 | 7-Mar-05 | Belvedere Cove, Richardson Bay | 1,611 | NA | 1,611 |
| 15 | 10-Mar-05 | Sausalito, Stink Plant | Trace | NA | NA |
| 16 | 25-Mar-05 | Richardson Bay | 795 | NA | 795 |
| Totals | | | 58,789 | 145 | 58,934 |

occurring within Richardson Bay, primarily in the subtidal beds of eelgrass and *Gracilaria spp*. A total of eight spawns occurred in Richardson Bay this season, and at times spawning almost seemed continuous. However, spawning events were distinguished by determining egg development and observing shifts in the areas spawned upon over time (i.e., from the main subtidal bed to the marinas). North-Central Bay spawning activity also included a spawn at Pt. San Quentin (290 tons), which included spawn along the shoreline from northwest of the Marin Rod and Gun Club (MRGC), the pier at MRGC, to the west end of San Quentin Prison. This was the first spawn of measurable size documented at this location in the 32-year history of the spawn survey (a trace amount of spawn was noted here in February of 2003).

Increased overall spawning biomass with significant improvements in the numbers of fish from age 4 through 6 cohorts, from the 2003-04 season, and the apparent strong recruitment of two-year-olds are positive signs of improvement for the San Francisco Bay spawning population. However, as in the last several years, the apparent low numbers of six-year-old herring (45 percent below average), and absence of older herring continue to be a cause of concern. This continued collapsed age structure, apparent reduction in size at age and/or poor condition, and potential El Niño effects give cause for continued conservative management measures for the stock.

### 3.3.1 San Francisco Bay Herring Young of the Year (YOY)

Pacific herring young-of-the-year (YOY) are commonly caught by the Department's Central Valley Bay-Delta Branch San Francisco Bay Study (SFBS) during the spring and summer of each year. The SFBS conducts surveys to determine the abundance and distribution of invertebrates and fishes in the Western Delta and San Francisco Bay. Stations are sampled using a variety of research nets and other equipment, including a midwater trawl that is towed obliquely through the water column to capture species inhabiting varying depths. An index of abundance is calculated for YOY Pacific herring (Interagency Ecological Program Technical Report 63).




The herring young-of-the-year (YOY) abundance index for 2004 shows a decline to pre-2000 levels (Figure 3.3). The strength of the YOY indices for the 2000 to 2003 year classes indicated favorable environmental conditions for YOY survival and growth within San Francisco Bay; however, the low indices for 2004 may reflect unfavorable conditions relative to growth. The low index may indicate poor recruitment of this cohort as it recruits to the spawning population in 2006-07 and 2007-08 seasons as 2- and 3-year-olds. However, there is no strong predictive relationship between the YOY abundance index and the subsequent numbers of two and three year-old herring that return to spawn. Survival to first reproduction is affected by a number of factors during the first two to three years of life, including predation, food availability, and competition.

### 3.4 Status of the Tomales Bay Spawning Population

The Tomales Bay 2004-05 spawning biomass estimate is 3,686 tons, a 70 percent decline from the 2003-04 biomass estimate of 12,124 tons. The spawning biomass estimate is nine percent less than the thirteen-season average of 4,061 tons (i.e., since the fishery was re-opened for the 1992-93 season). It is not uncommon for the spawning biomass population in Tomales Bay to fluctuate from season to season (Table 3.2). Environmental conditions offshore and in Tomales Bay play a key role in the fluctuation of spawning biomass. A decline in spawning biomass was not unexpected this season, after the second highest biomass estimate in the history of the Tomales Bay roe herring fishery in the 2003-04 season, but the recent El Niño may have precipitated the decline. El Niño events often create unfavorable environmental conditions for herring due to changes in ocean dynamics; for example, decreased coastal upwelling. These changes may lead to temporal effects in the food web, increased competition, predation, and altered migration patterns.

The first fifteen seasons of the Tomales Bay-Bodega Bay roe herring fisheries, from 1972-1987, was a cool water period, dominated by La Niña events. Above average spawning biomass estimates were found in eleven out of the fifteen seasons. (In two of the fifteen seasons spawning biomass surveys were not conducted.) These periods of cool water are thought to be more beneficial for Pacific herring. The period after the fishery was re-opened for the 1992-93 season has been marked by frequent El Niño events of varying magnitude. For example, the weak-to-moderate 2002-03 El Niño did not appear to greatly impact herring in Tomales Bay in 2003-04. However, the strong 1997-98 El Niño had lasting effects including a low spawning biomass estimate of 586 tons (Table 3.2). The post 1997-98 El Niño herring spawning biomass in Tomales Bay has shown a general trend towards improvement, but the loss of older age classes remains a concern. Oceanic temperatures in recent seasons indicate a cooling trend, which is often favorable to herring, and is reflected in the spawning biomass estimates over this period. Despite the loss of older age classes, there are positive signs of improvement, as 2-, 3-, and 4-year-old herring have shown up in unprecedented numbers in recent seasons (Table 3.3).

Herring cohorts in Tomales Bay typically do not track well.  Improvements in spawning biomass since 1992-93 indicate recovery that can not be attributed

Table 3.2 Season Spawning Biomass for Tomales Bay

| Season | Spawn Escapement (tons) | Catch (tons) | Percent Catch (Exploitation Rate) | Spawning Biomass (tons) |
|---|---|---|---|---|
| 1972-73 [a, 1] | --- | 598 | --- | --- |
| 1973-74 [a] | 6,041 | 521 | 7.9% | 6,562 |
| 1974-75 [a] | 4,210 | 518 | 10.9% | 4,728 |
| 1975-76 [b] | 7,769 | 144 | 1.8% | 7,913 |
| 1976-77 [b] | 4,739 | 344 | 6.7% | 5,083 |
| 1977-78 [b] | 21,513 | 646 | 2.9% | 22,163 |
| 1978-79 [c, 1] | --- | 448 | --- | --- |
| 1979-80 [c] | 5,420 | 603 | 10% | 6,023 |
| 1980-81 [c] | 5,128 | 448 | 8% | 5,576 |
| 1981-82 [c] | 6,298 | 851 | 11.9% | 7,149 |
| 1982-83 [c] | 10,218 | 822 | 7.4% | 11,040 |
| 1983-84 [c] | 1,170 | 110 | 8.5% | 1,280 |
| 1984-85 [d] | 6,156 | 430 | 6.5% | 6,586 |
| 1985-86 [d, 2] | 435 | 771 | 12.8% | 6,000[2] |
| 1986-87 [d] | 4,931 | 867 | 14.9% | 5,798 |
| 1987-88 [d] | 1,311 | 750 | 36.4% | 2,061 |
| 1988-89 [d] | 167 | 213 | 56% | 380 |
| 1989-90 [e] | 345 | 0 | 0% | 345 |
| 1990-91 [e] | 779 | 0 | 0% | 779 |
| 1991-92 [e] | 1,214 | 0 | 0% | 1,214 |
| 1992-93 [f] | 3,850 | 222 | 5.5% | 4,072 |
| 1993-94 [f] | 2,245 | 219 | 8.9% | 2,464 |
| 1994-95 [f] | 3,705 | 275 | 6.9% | 3,980 |
| 1995-96 [f] | 1,730 | 355 | 17% | 2,085 |
| 1996-97 [f] | 1,288 | 222 | 14.7% | 1,510 |
| 1997-98 [f] | 586 | 0 | 0 % | 586 |
| 1998-99 [f] | 4,017 | 54 | 1.3% | 4,071 |
| 1999-00 [f] | 1,968 | 42 | 2.1% | 2,010 |
| 2000-01 [g] | 3,897 | 298 | 7.1% | 4,195 |
| 2001-02 [g] | 6,889 | 354 | 4.9% | 7,243 |
| 2002-03 [g] | 4,304 | 78 | 1.8% | 4,382 |
| 2003-04 [g] | 11,844 | 280 | 2.3% | 12,124 |
| 2004-05 [g] | 3,656 | 30 | 0.8% | 3,686 |
| AVERAGE | 4,580 | 214 | 8.9% | 4,938 |
| ’92-03 to ’04-05 AVG | 3,845 | 187 | 5.6% | 4,031 |
| Mesh Study Average | 6,118 | 208 | 3.4% | 6,326 |

[a] Catch with round haul gear from Tomales Bay.

[b] Catch includes the use of round haul and gill net gear types, and herring caught from both Tomales Bay and Bodega Bay.

[c] Catch is by gill net only, includes catch from Tomales and Bodega Bay. Use of round haul gear prohibited since 1978-79 season, in Tomales Bay and Bodega Bay.

[d] Catch is by gill net only with minimum mesh size of 2-in., includes catch from Bodega Bay.

[e] Tomales Bay fishery is closed. Bodega Bay fishery remains open with gill nets, minimum mesh size of 2-in.

[f] Bodega Bay fishery is closed and Tomales Bay fishery is re-opened with gill nets with a minimum mesh size of 2 1/8–in.

[g] Bodega Bay fishery remains closed. Gill nets with a minimum mesh size of 2-in. are allowed during the gill net mesh study, in progress. The mesh study is being conducted to evaluate the use of a minimum mesh size of 2-in. gill nets on the Tomales Bay herring population.

[1] Spawning ground escapement survey not conducted to generate the spawning biomass.

[2] Spawning biomass estimated by cohort analysis for this season.

Table 3.3 Estimated Numbers (x1,000) of Herring-at-Age in the Tomales Bay Spawning Population, 1993 to present

| | Age and Percent Composition | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Season | 1 | % | 2 | % | 3 | % | 4 | % | 5 | % | 6 | % | 7 | % | 8 | % | 9 | % | Total |
| 93-94 | 0 | 0 | 567 | 2.8% | 3,329 | 16.7% | 6,021 | 30.1% | 3,329 | 16.7% | 5,171 | 25.9% | 1,062 | 5.3% | 425 | 2.1% | 71 | 0.4% | 19,974 |
| 94-95 | 0 | 0 | 4,446 | 13.9% | 10,209 | 32.0% | 4,281 | 13.4% | 3,293 | 10.3% | 5,846 | 18.3% | 2,717 | 8.5% | 988 | 3.1% | 165 | 0.5% | 31,945 |
| 95-96 | 0 | 0 | 1,000 | 5.6% | 1,643 | 9.2% | 7,287 | 40.6% | 5,930 | 33.1% | 1,072 | 6.0% | 214 | 1.2% | 786 | 4.4% | 0 | 0.0% | 17,932 |
| 96-97 | 0 | 0 | 117 | 1.0% | 2,225 | 18.4% | 4,625 | 38.2% | 4,098 | 33.8% | 820 | 6.8% | 234 | 1.9% | 0 | 0.0% | 0 | 0.0% | 12,118 |
| 97-98 | | | | | | | | | | | | | | | | | | | |
| 98-99 | 0 | 0 | 11,655 | 25.1% | 14,127 | 30.5% | 14,598 | 31.5% | 4,827 | 10.4% | 1,177 | 2.5% | 0 | 0.0% | 0 | 0.0% | 0 | 0.0% | 46,383 |
| 99-00 | 0 | 0 | 487 | 2.2% | 5,606 | 25.4% | 10,603 | 48.1% | 4,753 | 21.5% | 244 | 1.1% | 366 | 1.7% | 0 | 0.0% | 0 | 0.0% | 22,059 |
| 00-01 | 0 | 0 | 6,983 | 16.7% | 17,642 | 42.1% | 15,437 | 36.8% | 1,838 | 4.4% | 0 | 0.0% | 0 | 0.0% | 0 | 0.0% | 0 | 0.0% | 41,900 |
| 01-02 | 0 | 0 | 19,379 | 25.3% | 35,776 | 46.8% | 17,060 | 22.3% | 4,306 | 5.6% | 0 | 0.0% | 0 | 0.0% | 0 | 0.0% | 0 | 0.0% | 76,521 |
| 02-03 | 0 | 0 | 15,113 | 29.3% | 22,589 | 43.8% | 11,613 | 22.5% | 2,148 | 4.2% | 80 | 0.2% | 0 | 0.0% | 0 | 0.0% | 0 | 0.0% | 51,542 |
| 03-04 | 0 | 0 | 45,193 | 31.7% | 55,565 | 39.0% | 26,548 | 18.6% | 11,483 | 8.1% | 2,593 | 1.8% | 1,235 | 0.9% | 0 | 0.0% | 0 | 0.0% | 142,616 |
| 04-05 | 0 | 0 | 10,560 | 25.0% | 18,170 | 43.1% | 9,498 | 22.5% | 3,481 | 8.3% | 472 | 1.1% | 0 | 0.0% | 0 | 0.0% | 0 | 0.0% | 42,181 |
| AVG | 0 | 0 | 10,500 | 16.2% | 16,989 | 31.5% | 11,597 | 29.5% | 4,499 | 14.2% | 1,588 | 5.8% | 530 | 1.8% | 200 | 0.9% | 21 | 0.1% | 45,925 |

Note: 1997-98 season not included due insufficient data set for expansion entirely to recruitment of younger fish; older fish either returned or emigrated from other areas. Similarly, the spawning biomass of 2003-04 was not built entirely from Tomales Bay stock, as the numbers of older herring went well beyond simple recruitment. It is possible that increased mortality of herring due to El Niño conditions is responsible for some of the decline this season; however, displacement of herring may be a more major cause of the decline considering that this El Niño appears to be weaker than the 2002-03 El Niño. Sea surface temperature (SST) monitoring of Northern California waters has shown that temperature anomalies vary in time and space. Each El Niño event impacts the herring population differently depending on the magnitude, timing, and locations of the anomalous SST occurrences in California waters. The locality and timing of warm water masses associated with El Niño may have displaced herring, and temporarily prevented herring from returning to Tomales Bay. Conversely, favorable environmental conditions during the 2003-04 season may have led to an influx of herring from other areas, which may have returned to those areas this season.

Commercial and research catch data collected this season demonstrate the effects of an El Niño. Herring returned to Tomales Bay underweight which typically reflects poor oceanic conditions. Herring caught commercially this season were slightly shorter, and showed an 11 percent reduction in weight compared to herring caught in the 2003-04 season. Research samples are collected using gill nets with several mesh sizes, which are designed to sample a broader size range and provide a better estimate of the entire spawning population than commercial gill nets.

Research sampled fish were on average 3-mm longer, but 10 percent lighter than herring caught in 2003-04. Spawning population lengths and weights collected this season were similar to those collected during the 2002-03 El Niño. The reduced weight of herring this season may be linked to unfavorable oceanic conditions and may account for a small portion of the decline in spawning biomass. Commercial catch data indicate that herring in the selectivity range of commercial nets were 2-mm longer, but six percent lighter than those caught in during the 2002-03 El Niño. The poor condition of herring this season helps to explain the poor commercial catch this season by fishermen.

Spawning biomass in Tomales Bay began to decline drastically in the late 1980's as a result of what would become a six-year drought. Drought conditions in Tomales Bay were thought to be the primary cause of the decline in spawning biomass. Without normal rainfall, bay salinities remain high and are not conducive for spawning. Poor spawning conditions may have led a large portion of herring to temporarily abandon Tomales Bay until conditions improved.

There were eight spawning events during the 2004-05 season totaling 3,656 tons of spawning escapement. Seventeen different spawning bed areas were utilized from November through February. The locality of spawning events showed a similar pattern to previous seasons, as spawning was confined to the southern half of Tomales Bay, however, the timing and magnitude of spawning changed this season. It was the first time since the 1999-2000 season that December spawning escapement did not account for at least 50 percent of the season's spawn escapement, as larger spawn events occurred in January. The spawning escapement total for January was the second highest since the 1992-93 season. Eelgrass (*Zostera marina)* and *Gracilaria spp.* resources in Tomales Bay remained healthy and provided plenty of suitable spawning substrate for herring. Environmental conditions in Tomales Bay (i.e., temperature and salinity) do not appear to be a factor in the decline in spawning biomass this season. It is more likely that offshore environmental conditions played a dominant role in the decrease in spawning biomass this season, although straying may also be a factor but not conclusive.

The Department is continuing a mesh size study for the Tomales Bay fishery. This study allows permittees to use a gill net mesh size of 2-in., which is smaller than the 2 ⅛-in. mesh required by regulation. The Department is evaluating the effects of using 2-in. mesh on the age classes caught by the commercial fleet to ensure that the younger fish (≤ 3-year-olds) are not significantly impacted, thus potentially causing the fishery to become unsustainable. There has been an increase in the proportion of younger fish in the population since the 2000-01 season. It is not surprising, given the smaller mesh size, that commercial catch data show an increased take of 3-year-old herring during the mesh study period, however, the take of 3-year-olds has remained at higher than expected levels. The expectation was that the Tomales Bay age structure was primarily older fish (≥ 4-year-olds) based on population assessments prior to the use of 2-in. mesh beginning in the 2000-01 season.

From 1993-94 to1999-2000 (prior to the mesh study), 3-year-old herring averaged approximately seven percent of the commercial harvest in Tomales Bay. During the mesh study (2000-01 to the present), 3-year-olds averaged 25 percent of the commercial catch. The increase in the percentage of 3-year-old herring taken by the fishery during the mesh study is a function of a number of factors including: large numbers of 3-year-olds in the spawning population (Figure 3.4); below-average numbers of 5-year-old and older herring; and a shift in size selectivity to include smaller younger herring, due to the gill net mesh size reduction to 2-in. It is likely that the use of 2-in. mesh gill nets in Tomales Bay has not had a detrimental effect on the age structure of the spawning population due to the low harvest rate during the study period (average 3.4 percent). However, the trend of increased harvest of 3-year-old herring is cause for concern (Figure 3.5). If the Tomales Bay stock should continue rebuilding, the commercial catch composition may shift to older age classes if they persist in the population.

El Niño conditions may have been a factor in this season's decline in biomass for the Tomales Bay stock, and it is unclear whether the Tomales Bay stock will rebound in the 2005-06 season. Recognizing that biological and environmental conditions vary, the Department will continue to maintain a conservative fishery management strategy (closure of the outer Bodega Bay fishery, conservative quotas, and monitor the 2-in. mesh study) to help ensure the sustainability of the Pacific herring population in Tomales Bay. If the Tomales Bay stock should continue rebuilding, the commercial catch composition may shift to older age classes as they persist in the population.

### 3.5 Status of the Humboldt Bay and Crescent City Spawning Populations

Herring appear to spawn almost exclusively on the vast eelgrass beds found in both the North and South Bays of Humboldt Bay. During a typical spawn event, herring schools may deposit eggs in low density over 300 acres of eelgrass. The spawn escapement estimate for the 2004-05 Humboldt Bay herring spawning season is 173 tons. This is a 66 percent decrease from last season's estimate of 505 tons and only 53 percent of the 9-year average of 328 tons from seasons when spawn assessments were conducted in Humboldt Bay. There were three separate spawn events found in the bay this year. The first spawn detected was in the North Bay on January 4th and was estimated at 29 tons. The next spawn took place close to one month later on February 3rd in the same location in North Bay and was estimated at approximately 20 tons. The last spawn detected this season occurred in the South Bay on February 4th and was estimated at 125 tons.

Due to the low numbers of herring landed during 2004-05 season the commercial catch was not sampled. The mean size for herring caught with the Department's variable-mesh gill net this season is 179 mm (range 148-225 mm), well below the mean lengths from the 2002-03, 2001-02 and 2000-01 seasons of 188 mm, 184 mm, and 188 mm, respectively.

Commercial Pacific herring landings were down again this season with just over 0.6 tons landed. This is the third season in a row that landings have been far below the 23-year Humboldt Bay average of 37 tons. The quota of 60 tons for Humboldt Bay has only been reached once since the 1997-98 El Niño and herring landings since that event averaging only 15 tons per year. A long-time Humboldt Bay herring permittee attributed these low landings to a disproportionate amount of small herring entering the bay, which were unavailable to commercial 2 ¼-in. mesh nets. Landing data from the Department's research nets appear to support this observation as approximately 91 percent (by number) of the herring caught during the 2004-05 season were captured in meshes 2-in. or less. Two of the last three season's biomass estimates were far below average; however, the exploitation rate during this 3-year period remained below one percent. The average yearly biomass estimate from the last five spawn assessment surveys, since the 2000-2001 season, is 389 tons. A 60-ton quota based on this average would result in a 15 percent exploitation rate, which is considered a conservative rate of harvest.

The Department of Fish and Game continued to work with University of

California Sea Grant, Humboldt State University, and Humboldt Bay Harbor District to monitor eelgrass biomass in Humboldt Bay. Agencies completed a full year of sampling with 10 sample sites in both the north, central and the south regions of Humboldt Bay. Above-ground eelgrass biomass (fresh weight) for winter 2004-2005 had a mean of 0.61 $kg/m^2$ (range 0.17-1.58 $kg/m^2$), which is a 21 percent increase from the winter 2003-2004 mean of 0.48 $kg/m^2$ (range 0.29-0.97 $kg/m^2$). This data is essential for herring research and has greatly improved the accuracy of the season's spawning biomass estimate.

Spawning ground surveys and commercial fishery assessments were not conducted in the Crescent City area for the 2004-05 season. No commercial fishing effort was reported in Crescent City during the 2004-05 season. The 30-year average of 22 tons is far below the 30-ton quota for this fishery. The Department does not plan to conduct spawning ground surveys or commercial fishery assessments in the Crescent City area for the 2005-06 season.

### 3.6 Areas of Controversy

Several areas of controversy are outlined in Section S.6 of this DSED. In particular, item numbers 7 through 11 are relevant for the 2005-06 season and have been of concern to the Department and the commercial herring industry for the past several seasons. An update to item number 2 is also provided in this section.

Item number 2, the importance of herring as a forage species for sea birds, marine mammals, and other fishes was addressed in Chapter 4 (Section 4.2.6.2) of the 1998 FED. A literature review on recent abstracts regarding predator/prey interactions with herring (Baraff and Loughlin 2000, Beamish et al. 2000, Bishop and Green 2001, Furness 1999, Haegele 1993, Hunt et al. 1999, Jauguet et al. 2004, Lance et al. 2002, Okey et al. 2004, Rooper and Haldorson 2000, and Sullivan and Butler 2002) indicates that are no new significant issues requiring additional mitigation measures relative to the proposed project since the 1998 FED. Some fish, birds and mammals may be affected by industrial fisheries but most of these animals are long-lived and generalist feeders that would find other food sources when herring (eggs, larvae, juvenile, and adult) are not available. The most important factor cited was setting conservative exploitation rates that recognize the importance of herring as a prey species for numerous marine animals.

Item number 7, status of the herring population in San Francisco Bay, is discussed in detail in Section 3.3 of this DSED. The Department is concerned about potential negative impacts on the San Francisco Bay population following the 2004-05 El Niño that may affect the 2005-06 season, and believes that the continuance of a conservative management strategy and measures to rebuild the stock are needed.

Item number 8, the independent peer review sought by the Department and the alleged violation of the Marine Life Management Act (MLMA), refers to the controversy based on the belief by some herring industry members that the Department violated the MLMA when a peer review on biomass assessment methodologies and preliminary use of a stock assessment model was done. The Department did not violate MLMA because the herring fishery is not subject to that Act until a fisheries management plan (FMP) is developed.

As mentioned in Section 3.2.3 of this DSED, and discussed in the 2004 FSED (Section 3.2.1), the Department sought the independent peer review in 2003 to evaluate the use of the Coleraine stock assessment model as an assessment tool and the two survey methodologies used to estimate the Pacific herring spawning biomass in San Francisco Bay (Appendix B). The model had not been previously used by the Department to assess the status of Pacific herring. California Sea Grant administered the peer review and assembled a panel of scientists with demonstrated expertise in modeling and assessing pelagic fish populations.

MLMA was passed in 1998 and became law on January 1, 1999, and is contained in Fish and Game Code Sections 7060-7090. MLMA provided a greater delegation of authority and responsibility to the Fish and Game Commission and the Department of Fish and Game for marine fisheries. It also mandates "…priority of long-term benefits and sustainability over short-term benefits in our use of marine resources, an ecosystem perspective that includes more than fisheries, and a strong emphasis on science-based management developed with the help of those most knowledgeable and concerned about the health of the ocean and our fisheries." (Webber and Heneman 2000). The primary goals of MLMA are to ensure the conservation, restoration, and sustainable use of California's marine living resources. To achieve this goal, MLMA requires that FMPs be developed for managing the State's fisheries. A more detailed description of FMPs is located in Section 1.3 of this DSED. Due to the large number and variety of marine fisheries in California, the time and effort needed to prepare an FMP, and the significant costs associated with FMPs, procedural guidelines and priorities were developed. MLMA is also a collaborative process and requires ongoing communication and participation from all those involved in developing an FMP, including sport and commercial fishermen, environmental and conservation groups, academic and scientific communities, and other interested parties (Department of Fish and Game DRAFT Master Plan 2001). Once an FMP is developed for a fishery, it is implemented through regulations adopted by the Fish and Game Commission. The Pacific herring fishery is among five California fisheries referenced in the MLMA section of the Fish and Game Code (Section 7059 (b)(2)) as a model to follow for "…[developing] a process for the involvement of interested parties and for factfinding and dispute resolution processes appropriate to each element in the marine life and fishery management process."

The Pacific herring fishery currently does not have an FMP. However, it does have a CEQA functional equivalent document (Section 1.2) which takes the place of an FMP until such time as one can be developed and implemented. The peer review that the Department sought on the Coleraine model and its survey methodologies does not fall under MLMA given this difference. When an FMP is completed for the Pacific herring fishery, it will be subject to all aspects of MLMA as well as CEQA, and will be functionally equivalent to an Environmental Impact Report (EIR).

The peer review that the Department received confirmed that the Coleraine model was appropriate to use as a preliminary assessment tool for herring until a more robust model can be developed. In addition, the peer review evaluated the scientific methods used to assess the Pacific herring fishery in San Francisco Bay, and made recommendations on the appropriate use of the survey methods for future population assessments. In effect, the Department is adhering to one of the mandates of MLMA which is to base decisions on sound science and best available information.

Item number 9, the use of the spawn deposition survey alone for biomass estimation, is referring to the concern of industry members with the Department's decision to stop utilizing the hydroacoustic survey as a method for estimating biomass in San Francisco Bay, and rely solely on the spawn deposition survey.

Hydroacoustic assessment is an accepted methodology for detecting presence, determining distribution, estimating biomass, and observing behavior for a variety of fish species. It is used to assess some herring stocks around the world either solely or in conjunction with another method. For example, the North Sea Herring Assessment is conducted using hydroacoustic methods along with a catch-at-age model. The hydroacoustic information is used in the model, and the model results are used to set the biomass estimate of the stock. The Alaska Department of Fish and Game assesses the Prince William Sound and Kodiak stocks using hydroacoustic and aerial surveys but does not use hydroacoustic surveys to assess the Southeast, Northeast Bering Sea, Togiak, or Cook Inlet stocks. They do identify some potential problems with duplication of schools and incomplete surveys due to the nature of the behavior of the fish in certain areas. The Washington Department of Fish and Wildlife utilize both spawn deposition surveys and hydroacoustic surveys while the Canadian Department of Fisheries and Oceans rely only on spawn surveys for their assessments. It is clear that hydroacoustic surveys work for some herring fisheries and not for others. Differences unique to those fisheries (i.e., open ocean versus bays and inlets) would be one factor.

While the hydroacoustic method is used in a variety of herring fisheries, the Department has determined that the spawn deposition survey is more accurate and precise, less variable and more predictable for San Francisco Bay than the hydroacoustic survey. This determination is based on: 1) the Department's own comparative analysis of the spawn deposition survey (Section 3.2.1) and the hydroacoustic survey (3.2.2) used to assess the herring population in San Francisco Bay as discussed in Section 3.2.3 of this DSED; and 2) the results of an independent peer review of our methodologies and use of a stock assessment model (Coleraine) as a possible assessment tool (Appendix B). In addition, spawn deposition surveys are used to assess the Tomales Bay and Humboldt Bay populations.

Item number 10, minimum mesh size reduction in San Francisco Bay from 2 1/8-in. to 2-in, refers to the ongoing controversy with the reduction of the minimum mesh size in San Francisco Bay from 2 1/8-in. to 2-in., and is discussed in Section 2.3.1.5 of this DESD. The mesh size reduction in San Francisco Bay involves the long term opinion held by some members of the commercial herring industry that a smaller mesh size would enable the fishery to catch the quota more efficiently without catching a large proportion of younger age fish (age 3 and younger). The older age classes (age 5 older) are either not well represented in the population or are absent altogether. The Department is concerned that a reduction in the minimum mesh size in San Francisco Bay would result in an increased take of 2- and 3-year-old fish. If the 2-in mesh should be adopted, the Department recommends that the harvest rate be lowered by lowering the quota for the 2005-06 season and that the use of the gear be monitored for a period of two to three years.

Item number 11, comparison of the Tomales Bay and the San Francisco Bay herring population age structure from 1993 through 2004, refers to the fact that the perceived need for a reduction in the minimum gill net mesh size from the existing minimum 2 ⅛-in. mesh by herring fishermen in San Francisco Bay has led to comparisons with Tomales Bay. Herring fishermen in Tomales are using smaller 2-in. mesh gill nets as part of a mesh-study. Fishermen have pointed out a number of similarities between the two bays, particularly the apparent similarities in age structure prior to adoption of the smaller 2-in. mesh in Tomales Bay in the 2000-01 season. However, there are differences between the two bays which is discussed in Section 3.6.1 of this DSED.

### 3.6.1 Comparison of Tomales and San Francisco Age Structure

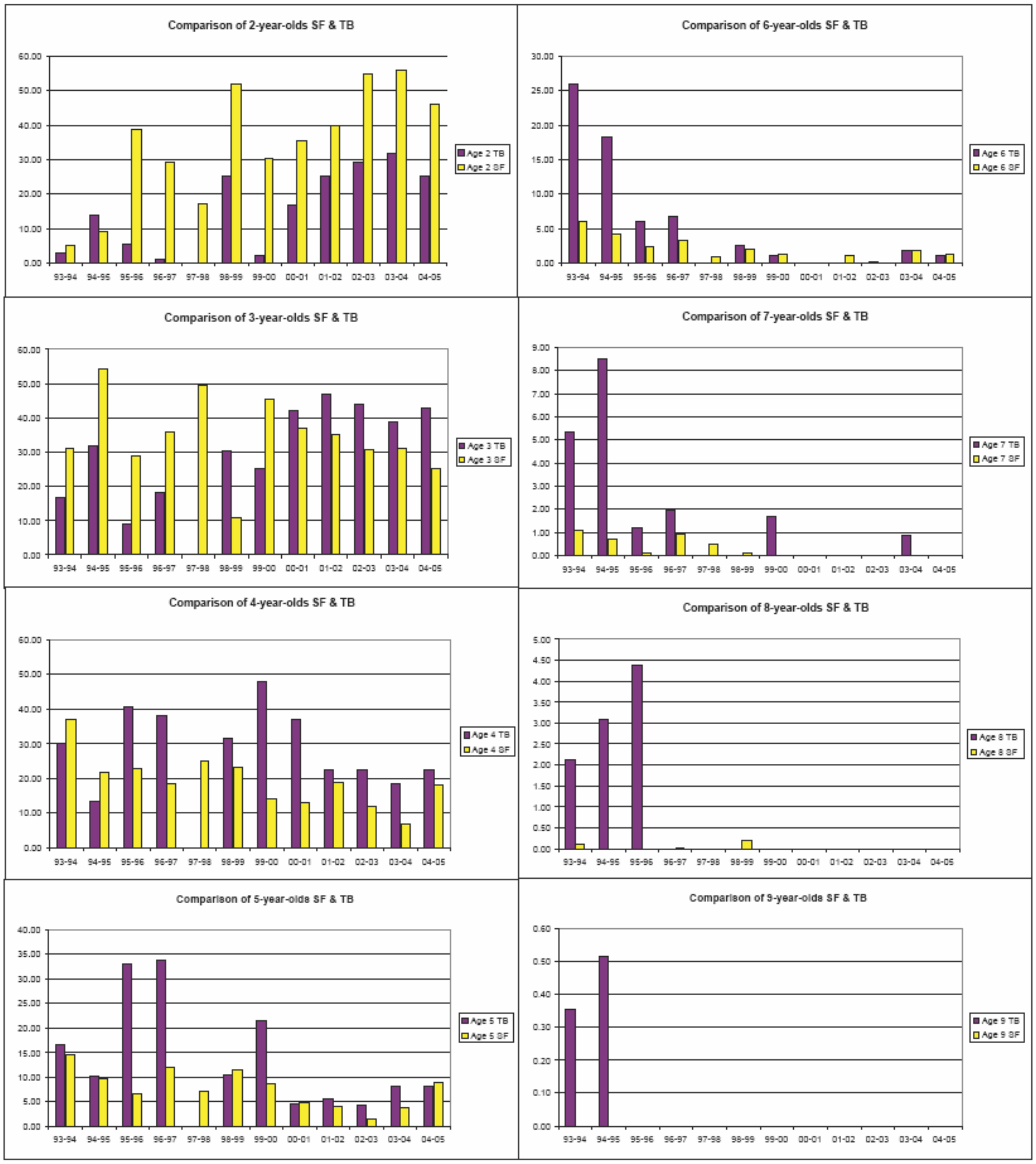
The purpose of this comparison is to analyze the results from the recent completion of a backlog of aging needed for Tomales Bay herring samples to thoroughly examine the age composition of both the spawning biomass and commercial catch in Tomales Bay.  Prior to reading the otoliths from herring samples in the commercial and research catch, lengths were being used to determine preliminary ages.

A more complete age data set exists for San Francisco Bay than for Tomales Bay.  Prior to the 1992-93 spawning season, the Tomales Bay herring population was not sampled for age composition.  Spawn sampling and commercial catch sampling was done by seasonal aids with supervision from a biologist from the Department's Monterey office.  When the new full-time biologist in the Bodega Bay area took over management of the Tomales/Bodgea Bay herring fishery in 1992-93, sampling also began for age composition of the spawning population.  However, age data from the commercial catch (i.e., samples taken from herring landings) does exist for Tomales Bay from 1972-73 to the present.  Due to the lack of comparable catch and population age composition data for Tomales Bay prior to 1992-93, only age data from both research and commercial samples for the last 12 seasons were examined for both bays.

Significant differences exist between the two bays and this has had some effect on age data collection.  The greatest differences are in the size and depth of these two bays and these two factors probably affect the behavior of pre-spawning herring the most.  To adequately assess the age composition the herring biomass in each bay, all schools need to be sampled.  The schools are larger and hold longer in the larger, deeper areas in San Francisco Bay and this makes research sampling easier than on the smaller schools in the smaller, shallower, Tomales Bay.  Additionally, sampling of pre-spawning schools to needs to occur prior to commercial fishing since this greatly alters the age composition of the school.  Given these factors, in Tomales Bay, in some seasons earlier schools were not adequately sampled and also sampling of some later schools was precluded by commercial fishing.  What this means in regard to this comparison of the age composition of the Tomales Bay spawning population, is that the numbers of larger, older herring which enter the bay in the earlier schools, may actually be slightly greater for some past seasons.  Recognizing this fact, the Department has made a great effort since the 2002-03 season to adequately sample all schools throughout the spawning season in Tomales Bay.

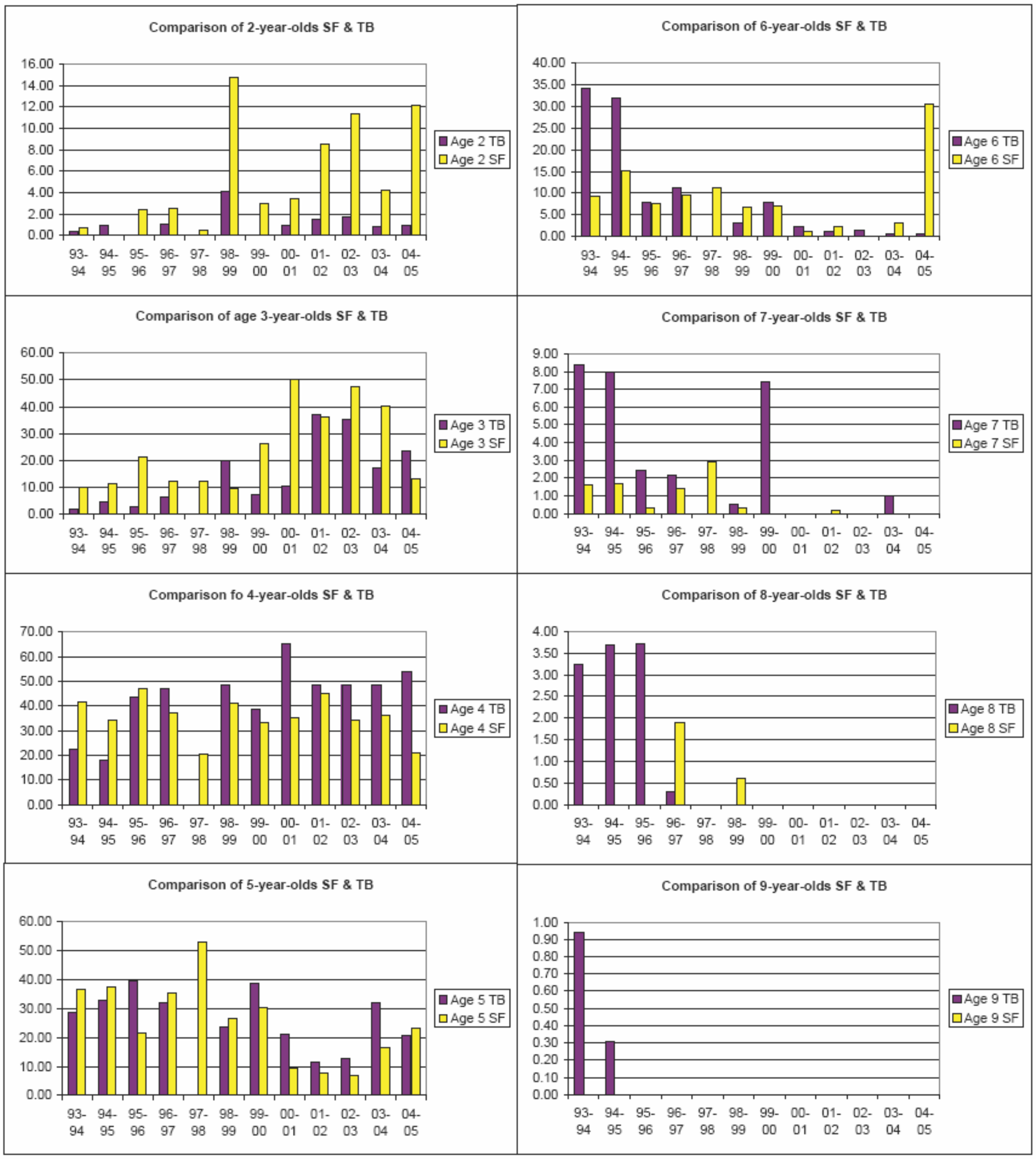
In recent years, Tomales Bay has been perceived as having a higher percentage of older herring than does San Francisco Bay. This was true in the early to mid 1990s when San Francisco Bay had higher percentages of 3-year-old herring while Tomales Bay had higher percentages of 4-year-old herring. The percentage of older herring changes with the three consecutive seasons starting in 2001-02 when Tomales Bay had slightly more 3-year-olds than San Francisco Bay and more 4-year-olds (Figure 3.4). This change is the result of a lack of 6-year and older fish and an increased proportion of 2-year-old fish in Tomales Bay.

Figure 3.4. Percent spawning biomass contribution for age 2 through 9 herring for San Francisco Bay and Tomales Bay for 1993-94 through 2004-05. There was no sampling for age composition in Tomales Bay in 1997-98, data were unavailable for comparison in those years.




It appears that the decline in abundance of larger, older fish is a problem for both Tomales Bay and San Francisco Bay from the mid-1990s through the present. This has occurred in Tomales Bay despite the low exploitation rate of the population in recent years (Figure 3.5).

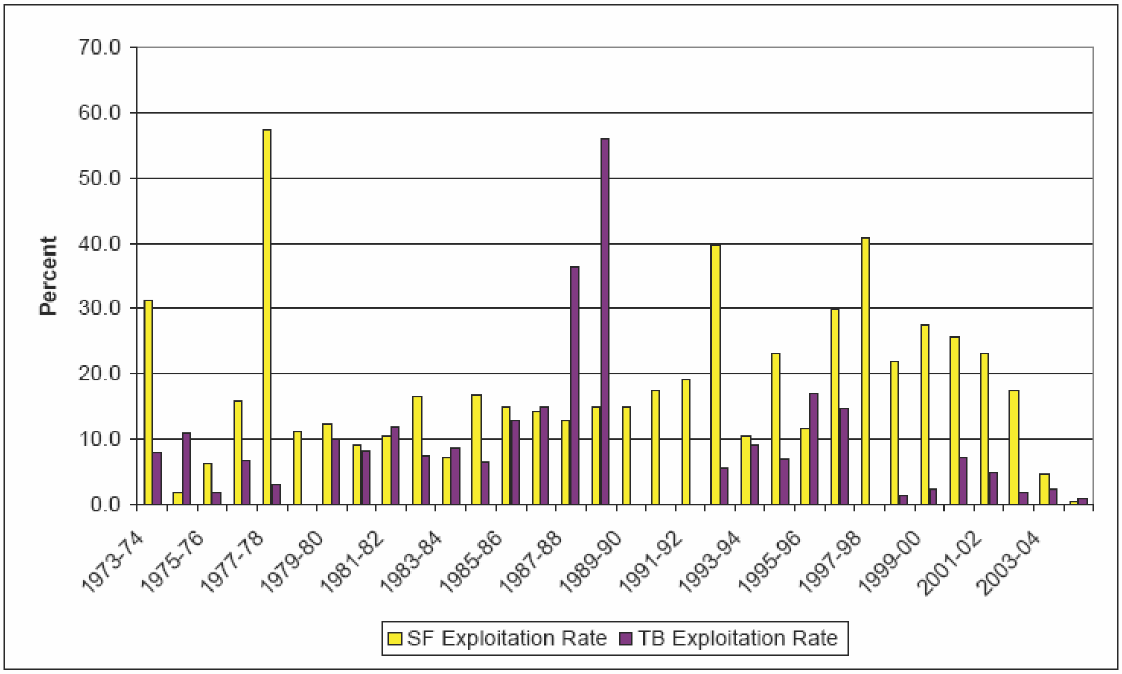
Figure 3.5 Percent commercial gillnet catch contribution for age 2 through 9 herring for San Francisco Bay and Tomales Bay for 1993-94 through 2004-05. There was no sampling for age composition in Tomales Bay in 1997-98, data were unavailable for comparison in those years.




In addition to environmental effects associated with El Niño events (discussed in Section 3.3 and 3.4), one explanation could be that the two bays share the same fish to some unknown extent. This concept, however, has been examined by a number of techniques since the early 1980s. Spratt (1981) for example, noted that the growth rate of Tomales Bay herring was significantly different than that of San Francisco Bay herring and that this may be evidence that the herring populations in the two bays are distinct. Reilly and Moore (1986) analyzed morphometric (i.e., measurement of body parts expressed as a ratio to standard length or some other measurement that is easily made) and meristic (count of body parts such as fin rays, vertebrate, spines, etc.) characteristics of California herring from Fort Bragg Harbor and San Francisco, Tomales, and Humboldt Bays, in an attempt to detect differences in herring from these locations. Analysis indicated that the northern populations (Humboldt Bay and Fort Bragg) could be separated from the southern populations (Tomales and San Francisco Bays) with an 85-87 percent success rate, but morphometric differences were not great enough to separate herring from Tomales and San Francisco Bays. Moser (1992) used parasites as biological tags in his study of juvenile herring off central California. His results suggested that Tomales and San Francisco Bay herring are separate spawning stocks and generally remain separate while at sea.

Beacham et al. (2002) used microsatellite variation to determine population structure of herring in British Columbia, with comparisons to California. The study determined a lack of genetic difference among herring stocks in British Columbia that was most likely caused by the high rate of straying between areas. For locations where genetically distinct populations occur, differences in timing of spawning are the main isolating mechanisms. Additionally, geographic isolation of the spawning population may also have some effect in maintaining genetic distinctiveness of the spawning population. The study found that herring spawning in California are distinct from those spawning in British Columbia.

Figure 3.6 Exploitation rates for Tomales and San Francisco Bays, 1974-75 through 2004-05.




The loss of older fish in a population may indicate an increase in mortality rates for those older age classes. This will happen whether the increased mortality arises from fishing or from natural causes. The low exploitation rates (i.e., small catches in relation to the spawning biomass) in Tomales Bay would indicate that the lack of older fish is not the result of fishing mortality (Figure 3.6). It is unlikely that the 2-in. minimum mesh size now allowed in Tomales Bay is solely responsible for these changes with an average exploitation rate over the last seven years of less than 5 percent.

Recently, the commercial catch of herring in Tomales Bay has consisted of fish from ages 3 to 7 years. Since the 2001-02 season, the catch of fish age 6 and older has been quite small, averaging 1.2 percent, by weight (2.2 tons), of the average 186-ton commercial catch for this period. For this same period, the Tomales Bay biomass averaged 6,859 tons, with age 6 and older fish comprising 69 tons of the total biomass. This represents an average 3.2 percent exploitation rate for fish 6 years and older and clearly can not account for the decline observed for age 6 and older herring in Tomales Bay.

In San Francisco Bay, the decline in abundance of older fish may have been the result of high exploitation rates. From the 1992-93 season through the 2002-03 season, exploitation rates may have been over 20 percent in all but two seasons and near or above 40 percent in 1992-92 and 1997-98, when comparing landings with the more conservative spawn survey biomass estimates (refer to Section 3.2.3) (Figure 3.6). Exploitation rates at these levels could be a factor in a decline in the mean age of the San Francisco Bay herring population. If Tomales Bay and San Francisco Bay both share the same fish, then this would help explain the similar decline in the Tomales Bay age composition.

Recently, several fish diseases have been implicated as major constraints in limiting age structure and survival of Pacific herring populations in Washington State. Hersberger et al. (2003) identified *Icthyophonus hoferi* and viral hemorrhagic septicemia virus (VHSV) as endemic pathogens in the Puget Sound herring metapopulation. Icthyophonus is age dependent, increasing in incidence as the fish grows older. VHS is maintained in low prevalence, primarily in young herring. Laboratory studies indicate that nominal stressors to wild herring, such as high seawater temperatures associated with El Niño events, can elicit overt diseases. VHS has been found in Southern California stocks of Pacific sardines, a clupeoid fish like Pacific herring (Cox and Hedrick, 2001). Pacific herring from San Francisco Bay were tested for VHS in the early 1990s and the virus was not found (William Cox, California Department of Fish and Game, personal communication).

A comparison of the age structure of commercial landings in Tomales Bay and San Francisco Bay (Figure 3.5) showed age composition trends that are similar to the population age structures (Figure 3.4). The concept that the Tomales Bay fishery caught older fish was true in the 1990s but showed a similar trend to San Francisco Bay in the lack of older fish in the 2000s. In general, the populations in both bays have similar age composition and are exhibiting similar trends in abundance for most year classes.

### 3.6.2 Potential Impacts of Herring Fishery Regulation Changes to Salmonids

There are several listed species of salmon and steelhead present in San

Francisco Bay that may be impacted by the proposed herring fishery regulation change to reduce the minimum gill net mesh size from 2 ⅛-in. to 2-in. Sacramento River winter-run Chinook salmon is listed as endangered under both the California Endangered Species Act (CESA) and the Federal Endangered Species Act (FESA), Central Valley spring-run Chinook salmon is listed as threatened under both acts, and the Central Coast California and Central Valley steelhead Evolutionarily Significant Units (ESUs) are listed as threatened by FESA. Pursuant to both endangered species acts, "take" includes any action that would kill or harm the fish, including capture, injury from passing through a gill net, changes in feeding or migration behavior due to fishing activities, and attraction of predators.

Although Sacramento River winter-run Chinook salmon smolts occur in Central San Francisco Bay during the late November to mid-March herring fishing season, increased take due to the proposed regulation change will probably be insignificant. The peak timing of winter-run smolt emigration (out-migration) past Chipps Island near Pittsburg (Contra Costa County) typically occurs in March. Therefore the majority of winter-run Chinook salmon juveniles are well upstream of the Bay during most of the herring fishing season. Also, most emigrating smolts remain in the main channels and move through the Bay relatively quickly and are therefore not likely to occur in the nearshore areas of Central Bay where gill nets are often set.

In 25 years of sampling, the California Department of Fish and Game's San Francisco Bay Study (Bay Study) collected winter-run smolts ranging from 52- to 218 mm [mean=129 mm FL (Fork Length), n=73] during the herring fishing season, with only 1 fish >200 mm FL. Due to their size, winter-run smolts are not likely to be captured by a 2-in. mesh gill net, but if the smolts encounter the nets, there is a small potential for increased take due to injury by passing through the gill net mesh. It has been well documented that juvenile Chinook salmon are very good swimmers and can avoid nets, even actively employed gear designed to sample them. Take due to disruption of migration and feeding patterns by fishing activity and the increased predation risk associated with the concentration of predators near fishing locations is also possible, but not likely to increase with 2-in. mesh.

Impacts to Central Valley spring-run Chinook salmon smolts by the proposed regulation change would also likely be insignificant. Since peak emigration of spring-run salmon smolts probably occurs in April, most juveniles are upstream of the Bay during the herring fishing season. Also, most emigrating spring-run smolts are too small to be captured by the gill nets; the Bay Study collected spring-run Chinook salmon ranging from 46- to 82 mm FL (mean=68 mm FL, n=15) during the herring fishing season. However, if the smolts encounter the nets, there is a small potential for increased take due to injury by passing through the gill net mesh. The potential for take due to disruption of migration and feeding patterns and the increased predation risk associated with fishing activities will probably not increase with the proposed 2-in. mesh.

Steelhead from both the Central Coast California and Central Valley ESUs occur in San Francisco Bay during the herring fishing season and the 2-in. mesh gill nets will likely result in take. Juvenile steelhead live in freshwater for 1 to 4 years, but most Central Valley and Central Coast steelhead emigrate after 2 years in freshwater, with peak emigration between January and May (Barnhart 1986, McEwan 2001). The Bay Study collected steelhead ranging from 112- to 277 mm FL (mean=213 mm FL, n=36) during the herring fishing season, which is consistent with the size range of smolting steelhead (Katie Perry, California Department of Fish and Game, personal communication). Because of their size, emigrating steelhead could be captured or injured by the herring gill nets and the number of steelhead taken will likely increase with a mesh change from 2 ⅛-in. to 2-in.

While there is little data to support the take of steelhead by the herring fishery, these fish are the most vulnerable salmonid species due to their life history while in the bay. It is the Department's opinion that there is the potential for a relatively small number Central Valley ESU steelhead to be taken by the herring fishery although most of these fish remain in the main channels during emigration and move through the Bay relatively quickly. However, gill nets set near the mouth of steelhead-producing streams in South and Central bays have a much higher likelihood of taking Central Coast California steelhead due to the orientation of the nets, which is parallel to shore. Steelhead occurs in several streams near herring fishing areas, such as Corte Madera Creek in Central Bay. National Marine Fisheries Service has prepared draft Critical Habitat maps for the Bay Bridges and South Bay hydrologic units (http://swr.nmfs.noaa.gov/salmon/maps.htm) that can be used to identify steelhead-producing streams.

Although the proposed 2-in. mesh gill nets could potentially result in an increased take of steelhead, the number of fish taken will depend on fishing practices. Central Coast California steelhead are probably most vulnerable to capture and injury by gill nets set near their natal streams, but take could be lessened by designating no-fishing zones near these streams. There also is a potential for take of steelhead due to disruption of migration and feeding patterns and an increased predation risk associated with fishing activities, but, as for Chinook salmon smolts, this will not likely increase with proposed 2-in. mesh.